

INTRODUCTION

The like-doublet element type injector is one of the two main candidates for the Space Shuttle Orbit Maneuvering Engine Thrust Chamber. Rocketdyne's L/D #1 injector has been extensively tested at Rocketdyne and NASA/White Sands test facilities in solid wall and regeneratively cooled chambers to determine its performance and heat transfer characteristics. However, the only bomb tests conducted to determine its stability characteristics were performed without film coolant being injected across the cavities which were tuned to the first tangential mode. The L/D #2 injector which has undergone extensive stability tests, did not have boundary layer film coolant injected across the cavity entrance as does L/D #1.

The injector is stabilized by acoustic cavities which have gradual sloping entrances to facilitate regenerative cooling in this area with minimum pressure drop and low fabrication cost. Tests on other NASA sponsored programs have indicated this inlet configuration to be unstable with certain injectors while a sharper-edge entrance was stable.

The purpose of the present program is to define the stability characteristics of the L/D #1 injector over the range of OME chamber pressures and mixture ratios. The specific objectives are as follows:

- 1) To determine whether stability has been influenced by injection of BLC across the cavity entrance.
- 2) If the injector is stable to determine the minimum cavity area required to maintain stability.
- 3) If the injector is unstable to determine the effects of entrance geometry and increased area on stability.

The injector and cavity configurations will be bomb-tested in solid wall thrust chamber hardware typical of a flight contour with fuel heated to simulate regenerative chamber outlet temperatures.

(NASA-CR-134359) SPACE SHUTTLE
MANEUVERING ENGINE REUSABLE THRUST CHAMBER
PROGRAM. TASK 11: LOW EPSILON
STABILITY TEST PLAN (Rocketdyne)
HC \$4.00

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TEST HARDWARE

The test hardware consists of the L/D #1 injector, solid-wall thrust chamber and cylindrical extension, the fuel manifold, and replaceable acoustic cavity rings.

The L/D #1 injector, shown in Fig. 1, has 186 elements arranged in 9 rows. Oxidizer orifice diameters range from 0.032 to 0.038 inches while fuel orifice diameters range from 0.028 to 0.033 inches. There are also 68 fuel orifices (0.020 inch diameter) to supply boundary layer coolant amounting to 2.7 percent of the total propellant flow. Under nominal conditions the injector pressure drops are 56 psi on the oxidizer side and 62 psi on the fuel side. The diameter of the injector face is 8.2 inches. The injector has been fired 284 times for a total duration of 1695 seconds. It has been dye-penetrant inspected to verify that all welds are sound.

The solid wall chamber and combustor extension are shown in Fig. 2. The distance from the injector face to the throat is 16 inches. The heat sink capability of the chamber allows firing durations of up to approximately 5 seconds. The chamber and extension are instrumented for high response chamber pressure measurements. Steady-state chamber pressure measurements are made in the acoustic cavities. Circular grooves are trepanned into the wall at several locations to provide backwall transient temperature measurements which are indicative of essentially one-dimensional heat flux values. Two ports for bombs are located in the center of the four-inch long extension.

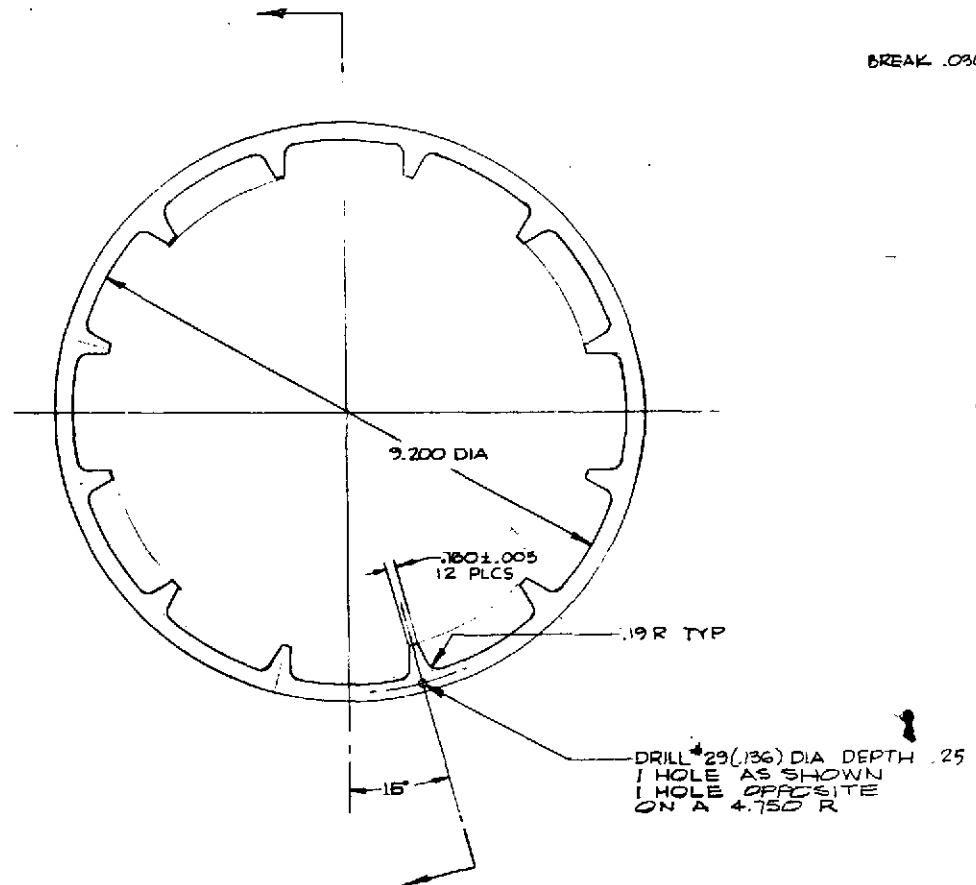
The fuel manifold (Fig. 3) distributes fuel to the injector and retains the acoustic cavity inserts. The acoustic cavities are formed by the injector and the replaceable two-piece cavity rings shown in Fig. 4. The aft ring defines the inlet geometry of the cavity and can be replaced with a new ring to provide a different inlet geometry without machining the forward ring. The forward ring defines the cavity width and depth. Only the forward ring need be modified to change the cavity depth. The rings are pinned together and to the fuel manifold to assure consistent orientation.

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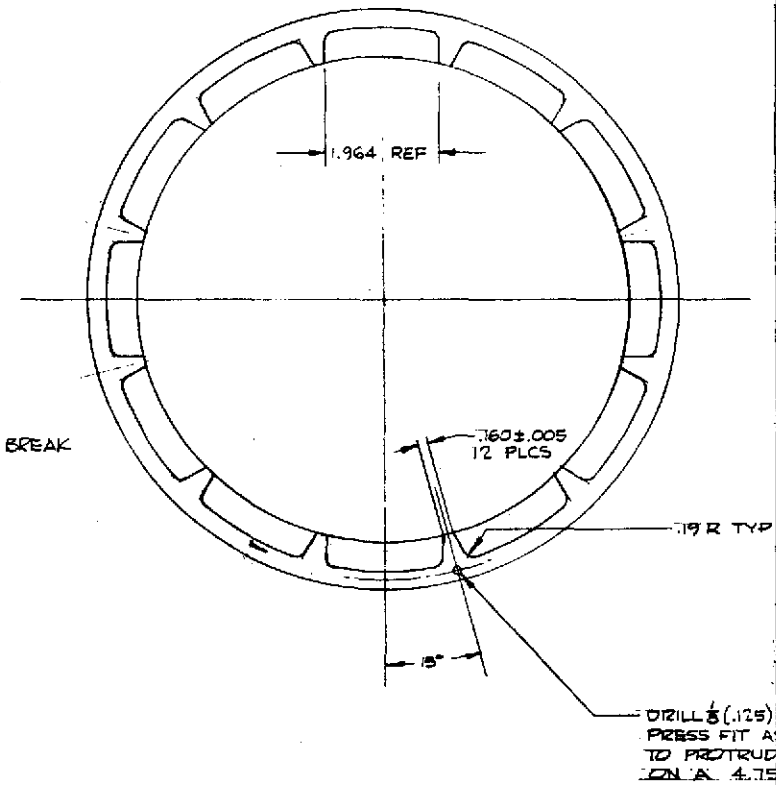
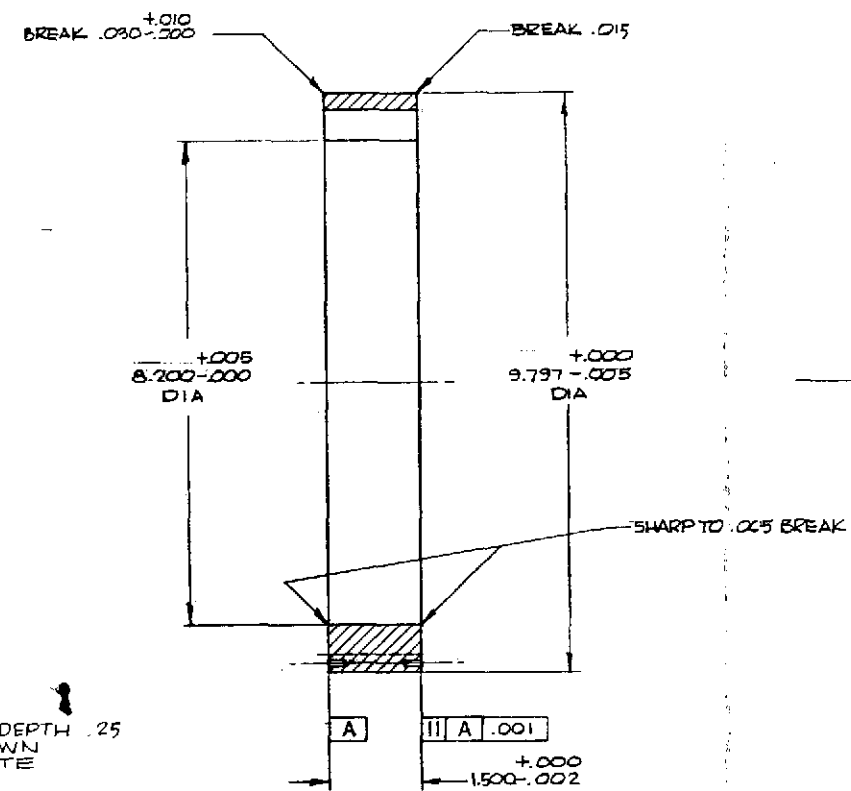
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-15 ACOUSTIC CAVITY RING



-15 ENTRANCE RING

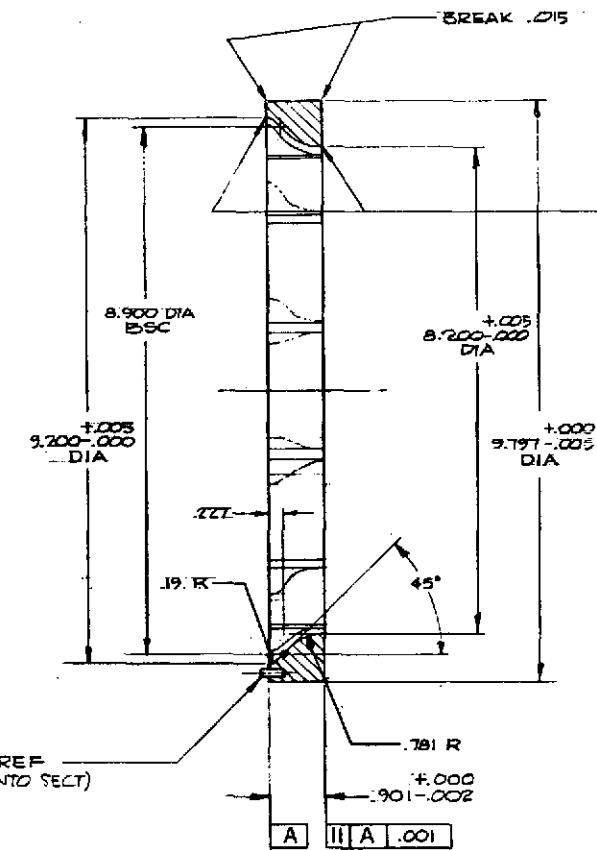


Fig. 4. Acoustic Cavity and Entrance Rings

The initial configuration of the rings provides the same configuration as that of the regeneratively cooled integrated thrust chamber. This provides a gradual entrance to the cavity which results in a gradual turn of the regenerative coolant passage in this area which maintains a low pressure drop. The same milling cutter is used in this area as for the throat and forward end of the chamber thereby eliminating additional set up costs during manufacturing. All cavities are of the same width (0.5 inches). Eight of the cavities are tuned (1.75 inch depth*) to stabilize the first radial mode; the remaining four cavities are 0.92 inches deep* to stabilize the third radial and first tangential modes.

TEST FACILITY

The tests will be conducted at the Victor Test Stand of the Rocketdyne Research Test Facility at Santa Susana. A schematic of the feed system is shown in Fig. 5. NTO and MMH will be supplied from pressurized tanks having maximum pressure capabilities of 2500 and 1500 psia respectively. The oxidizer flows to the engine at ambient temperature while the MMH is batch heated in the quantities required for a single firing through the use of a 4.5 gallon heat exchanger (limited to 430 psia) located immediately upstream of the main fuel valve. In this heat exchanger, hot water flows inside four concentric coils of one-quarter inch O.D. stainless tubing and provides a temperature limited heat source for the fuel. The heating water is circulated in a closed system from a steel reservoir tank through a 2.5 gpm Burke pump, past an 18 kilowatt Chromalox electrical heater, and then through either the heat exchanger or a bypass loop back to the reservoir. An alternate supply of cold water can be introduced into the system to quickly cool the heat exchanger between tests and thus permit test personnel to work in the immediate vicinity of the heater test stand. Heat up and cool down time for the system are both approximately 10 minutes and conveniently fit into the pretest and posttest procedures so that negligible delays in the firing schedule are introduced.

The NTO and MMH pass through 40 μ filters before entering the engine valves. GN_2 purges are supplied downstream of the engine valves.

*Effective acoustic depth

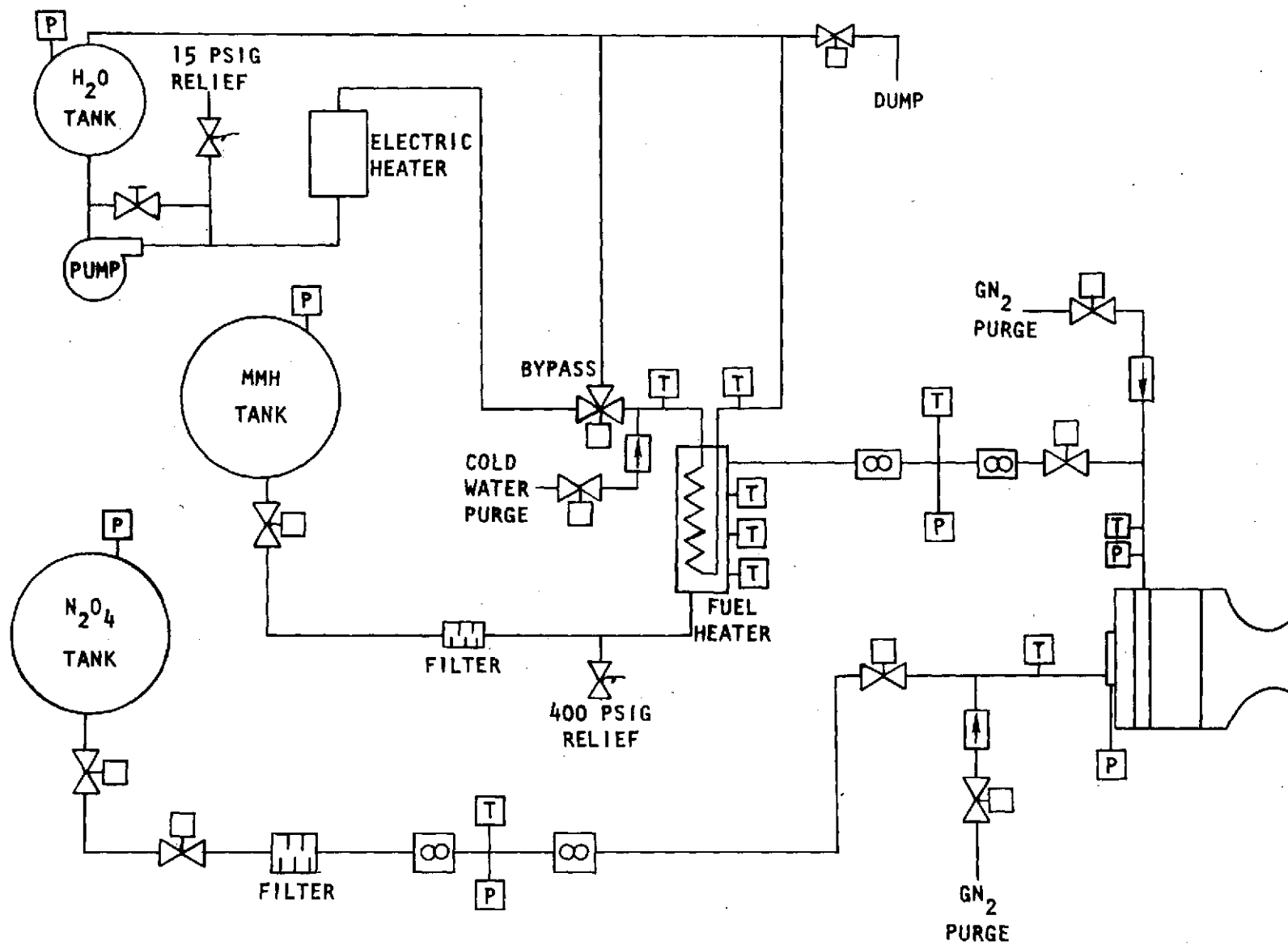


Figure 5 Propellant Feed Systems and Instrumentation Schematic

INSTRUMENTATION

High response pressure pickups will be used to monitor chamber pressure. Three type 317 Photocon transducers will be mounted in the cylindrical spool approximately 2 inches from the injector face at 12, 108, and 228 degrees location. The steady-state value of chamber pressure will be measured using two Taber type transducers with sensing ports located in the acoustic cavities. These same type transducers will be used to measure the fuel and oxidizer injection pressures and the feed system pressures. The temperature of the gas in the acoustic cavities will be measured using tungsten/rhenium thermocouples. Chromel/alumel thermocouples will be used to measure the thrust chamber wall temperature. Propellant feed system temperatures will be measured with iron/constantan thermocouples. Two turbine flow meters will be used to measure each propellant flow rate. Thrust will also be measured for computation of c^* . The instrumentation is listed in Table 1. The estimated precision of each of the critical measurements (thrust, chamber pressure, and flow rate) is 0.25 percent.

High response data will be recorded on tape and oscillograph. The oscillograph will also be used to record the slower responding chamber pressure measurements, the flow rates, and the injection pressures. Most data except the high speed data will also be recorded on a digital tape. Direct inking charts will be used to provide quick-look data.

TEST PROGRAM

The test program is structured to investigate three different acoustic cavity configurations with multiple tests scheduled for each configuration. The logic for selecting the configuration is shown in Fig. 6. Initial testing will be done with the acoustic cavity configuration which is incorporated into the integrated thrust chamber, i.e., 14.8 percent open area with gradual entrance. In order to minimize inactive time on the facility the two subsequent configurations to be tested will be fabricated based on the results of the first test series. If the ITC cavity configuration is stable two con-

TABLE 1

INSTRUMENTATION LIST FOR L/D #1 STABILITY PROGRAM

Parameter/Measurement	Symbol	Transducer Employed	Recording System			
			Beckman Digital Data System	Direct Reading Recorder	Oscillograph	Tape
<u>MMH (Fuel) System</u>						
MMH Tank Pressure	PFT	Taber*		X		
Fuel Flowrate #1	WF-1	Turbine Flowmeter	X	X	X	
Fuel Flowrate #2	WF-2	Turbine Flowmeter	X	X	X	
Fuel Line Pressure	PFL	Taber	X	X		
Fuel Line Temperature	TFL	I/C TC**	X	X		
Fuel Heater Temperature #1	TFH-1	I/C TC		X		
Fuel Heater Temperature #2	TFH-2	I/C TC		X		
Fuel Heater Temperature #3	TFH-3	I/C TC		X		
Fuel Injection Temperature	TFI	I/C TC	X	X		
Fuel Injection Pressure	PFI	Taber	X	X	X	
<u>N₂O₄ (Oxidizer) System</u>						
N ₂ O ₄ Tank Pressure	POT	Taber		X		
Oxidizer Flowrate #1	WOX-1	Turbine Flowmeter	X	X	X	
Oxidizer Flowrate #2	WOX-21	Turbine Flowmeter	X	X	X	
Oxidizer Line Pressure	POL	Taber	X	X		
Oxidizer Line Temperature	TOL	I/C TC	X	X		
Oxidizer Injection Temperature	TOI	I/C TC	X	X		
Oxidizer Injection Pressure	POI	Taber	X	X	X	

TABLE 1 (Cont'd)

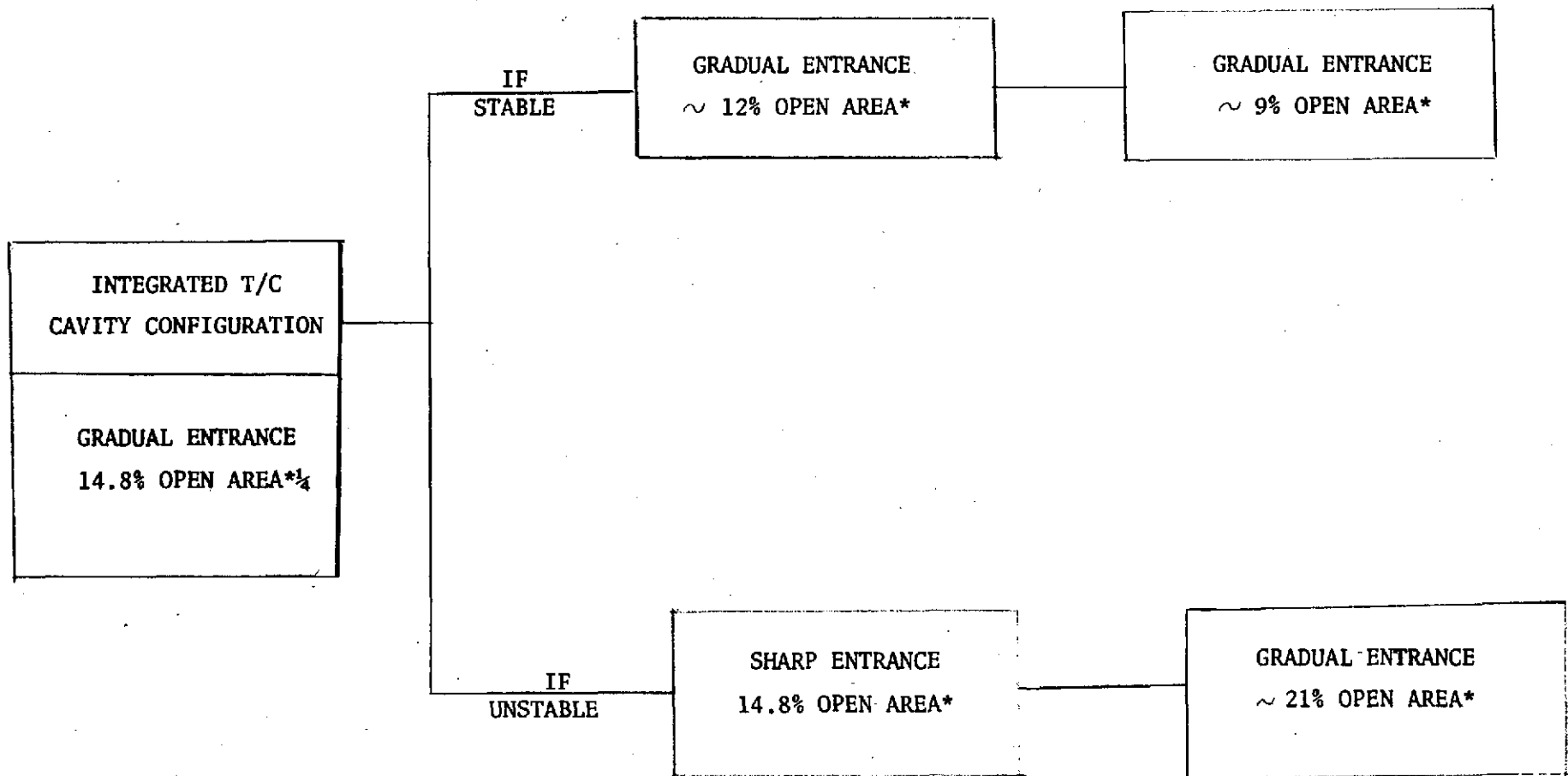
INSTRUMENTATION LIST FOR L/D #1 STABILITY PROGRAM

Parameter/Measurement	Symbol	Transducer Employed	Recording System			
			Beckman Digital Data System	Direct Reading Recorder	Oscillograph	Tape
<u>Thrust Chamber</u>						
Cavity Temperature #1	TC-1	W/R TC***	X	X		
Cavity Temperature #2	TC-2	W/T TC	X	X		
Cavity Temperature #3	TC-3	W/R TC	X	X		
Cavity Temperature #4	TC-4	W/R TC	X			
Cavity Temperature #5	TC-5	W/R TC	X			
Cavity Temperature #6	TC-6	W/R TC	X			
Chamber Pressure #1	PC-1	Taber	X	X		
Chamber Pressure #2	PC-2	Taber	X	X	X	X
Thrust	F	Load Cell	X	X		
Chamber Photocon #1	PCPH-1	Photocon			X	X
Chamber Photocon #2	PCPH-2				X	X
Chamber Photocon #3	PCPH-3				X	X
<u>Miscellaneous</u>						
Water Temperature @ Water Tank	TW-WT	I/C TC		X		
Water Temp @ Water Heater Outlet	TW-WHO	I/C TC		X		
Water Temp @ Fuel Heater Inlet	TW-FHI	I/C TC		X		
Water Temp @ Fuel Heater Outlet	TW-FHO	I/C TC		X		
Reference Junction Temperature	RJT	I/C TC	X			
Fuel Main Valves Power & Travel	---	-----	X		X	
Oxid. Main Valve Power & Travel	---	-----	X		X	X
Film Coolant Flowrate	WBLC	Turbine Flowmeter	X	X	X	

*Taber Strain Gage Pickup

**Iron/Constantan Thermocouple

***Tungsten/Rhenium Thermocouple



*AREAS OF PRIMARY CAVITIES - SECONDARY
CAVITIES HAVE 1/2 THE AREA OF THE PRIMARY

Fig. 6. Configuration Logic Diagram

figurations having smaller areas will be fabricated and tested to determine the stability bounds of this configuration.

Should the original configuration prove unstable two variations will be made to enhance the stability. One variation will be to increase the cavity area while maintaining the gradual entrance type geometry. The other configuration will maintain the original area in conjunction with a sharp-edged entrance configuration.

Three test periods will be scheduled. Each cavity configuration will be tested over the range of conditions shown in Table 2 as time allows. Since the duration of the test period may not permit conducting all five tests, the tests will be conducted in the sequence indicated by the numbers. Two 6.5 grain bombs will be detonated in the chamber during each test.

TABLE 2
TEST MATRIX

		MIXTURE RATIO		
CHAMBER PRESSURE, PSIA		1.45	1.65	1.85
	140	2		3
	125		1	
	110	4		5